The history and evolution of sutures in pelvic surgery

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Summary

The purpose of the study is to review the history and innovations of sutures used in pelvic surgery. Based on a review of the literature using electronic- and hand-searched databases we identified appropriate articles and gynaecology surgical textbooks regarding suture for wound closure. The first documented uses of suture are explored and then the article focuses on the use of knotted materials in pelvic surgery. The development of suture of natural materials is followed chronologically until the present time where synthetic suture is implanted during countless surgeries every day. This millennial history of suture contains an appreciation of the early work of Susruta, Celsus, Paré and Lister, including a survey of some significant developments of suture methods over the last 100 years. Most surgeons know little about the history and science of sutures. A retrospective view of suture is critical to the appreciation of the current work and development of this common tool.

Introduction

Suture, along with the knife and cautery, is one of the three basic tools that surgeons have had in their possession for thousands of years. Suture now is commonly used for most basic and complex surgeries. Few surgeons realize that behind the familiar foil packaging is an extensive history. It is not possible to mention all the valuable papers that have been written on suture. Instead we have traced the evolution of sutures, and chosen a selection of the excellent descriptions of suture which were made by surgeons and scientists; these papers might help to give historical context to our current surgical principles. The purpose of the study is to review the historical evolution of sutures used in pelvic surgery.

Methods

A combined hand- and electronic-search strategy was necessary to adequately select studies for this historical review. A systematic review was performed using MEDLINE and OLD MEDLINE, and select textbooks were searched January 1950 – July 2010. English language articles were selected with the terms 'suture', and 'history'. We supplemented these sources by hand-searching bibliographies of gynaecologic surgery textbooks, hand-searching historical libraries, and querying experts.

Results

Ancient times

The synthetic suture materials in use today are the result of surgical experience from approximately

3000 years BCE (Before Common Era). Ancient Egyptians sutured using plant fibres, hair, tendons and wool threads, which have all been found in mummified remains.[1] Edwin Smith (1822–1906) discovered a papyrus of medical knowledge codified in 1600 BCE. The papyrus bearing Smith's name is a roll more than 15 feet long with over 500 lines of text and 48 illustrations of medical treatments of trauma. The Edwin Smith papyrus is the oldest known surgical text in the history of civilization and is currently on long-term loan from the New York Academy of Medicine to the New York Metropolitan Museum of Art. Suture is mentioned in several of the 48 cases described in detail on the papyrus. For example, on the subject of treating a laceration, the papyrus reads, 'If thou findest that wound open and its stitching loose thou shouldst draw together for him the gash with two strips of linen'.[2] It was common for Egyptian embalmers to stitch up a corpse after removing organs using this manner of suturing.[3]

The first known document specifically discussing suturing techniques is the *Samhita,* written by the Indian surgeon Susruta in 500 BCE.[4] Susruta recommended irrigating foreign material from the wound, and then 'Large black ants should be applied to the margins of the wound and their bodies then severed from their heads, after these have firmly bitten the part with their jaws'.[5] The insect jaws effectively stapled the incision shut. Susruta also described the use of bow string made of sheep upper small intestine as suture for rhinoplasty, tonsillectomy, amputation, and repair of anal fistulae. At that time, catgut was readily available from musicians who used the material for stringed instruments. The process for creating bow strings for musical instruments was called 'kitgat' meaning fiddle string. A 'kit' was a three-stringed violin. From this word came 'catgut'.[4]

It would be nearly 200 years before logic in medical thinking and teaching would be revived by Hippocrates and his disciples in ancient Greece. Beginning in 300 BCE, they contributed both to the surgical and the medical aspects of the discipline. Roman medical journalist and teacher, Aurelius Cornelius Celsus (25 BCE–50 CE), wrote the eight-volume *De Re Medicina* in about 50 CE in which he described the use of braided suture.[6] Today surgeons imitate the elegant thinking of Celsus when placing a suture ligature for haemostasis. Celsus wrote about controlling haemostasis by 'making ligatures in many places' which would twist around the vessels.[6] Celsus described the symptoms of infection in a sutured wound as calor, rubor, tumor and dolor, which are taught in contemporary medical schools to this day. Later, Galen of Pergamon (131–211) was the first to describe the use of gut string as a suture material to sew severed tendons in gladiators.[7] Like Celsus and Hippocrates, Galen recommended copious irrigation of wounds with diluted wine and then wound closure with sutures. Galen also recommended using silk suture when available. Galen's teachings persisted for centuries after his death.

During the eighth century the standard for wound haemostasis was cautery. Bleeding wounds and vessels were commonly burnt with heated oils, but this also caused severe damage to the surrounding tissue. There are several surgeons of note from this time who had an early appreciation of suture. Rhazes (850–923) in Baghdad, who started his adult life as a minstrel and transitioned into a career as a physician, continued the use of catgut lute strings for abdominal wall repair. For his patients, he also utilized horse hair suture, a practice which persisted for centuries.[8] Ali Ibn Sina, or by his Latin name, Avicenna (980–1037), practised in the area of present day Iran approximately 60 years after the death of Rhazes. Avicenna noted the rapid dissolution of sutures in the presence of infection during anal fistula repair. He described a natural monofilament suture, pig's bristles, in a search for a more suitable suture material in *The Canon of Medicine*.[9] Avicenna described the use of a loop of suture for abdominal closure, which avoids the weakest part of a suture, the knot. About the same time Abulcasis who was born in 936 CE near Cordova in the Western Caliphate (present-day Spain) also produced a detailed description of cautery. In spite of Avicenna's surgical creativity, Abulcasis' work on cautery subjugated suture techniques at the time.

During the Middle Ages much of the preceding knowledge was kept by monasteries whose monks translated and copied texts. Little medical innovation occurred during the fifth to 15th centuries.

16th to 18th centuries

The period of the 16th to 18th centuries saw minimal change in materials, although discussion

Figure 1
Dawson's wire twister (above) and Charriere's wire twister (below)

about asepsis and suture techniques contributed to the discipline. Ambroise Paré (1510–1590), a Frenchman from a humble background who became a military surgeon aged 27, avoided cauterizing open wounds with boiling oil and re-introduced suture ligation methods recommended by Galen, Celsus and Avicenna for use after limb amputation.[10] He also warned about leaving dead space when closing a wound too shallow. Paré used fine linen strips and silk for vascular ligatures. Ambroise Paré is portrayed in Émile Picault's bronze bust of the 16th-century French surgeon showing a surgical saw and open book embellished with his famous motto – 'Je le pansay, Dieu le guarit' – ('I tended his wound; God cured him').

19th to early-20th century

Little was yet known of the absorption properties of the suture material until American physician Philip Syng Physick (1768–1837) began lecturing on the subject among the medical schools of Philadelphia. Physick, the first professor of surgery at the University of Pennsylvania, noted that fluids escaping from a wound dissolved leather, and he believed ligatures that dissolved would be helpful.[11] Physick used and popularized chromic sutures; although he published little, Physick's contributions are part of textbooks of the time.[12] Nineteenth century surgical catalogues would later market absorbable sutures made of 'tendons from the ox, moose, reindeer, etc., and the tails of rabbits, opossums, kangaroos and whale'.[13]

The use of silver wire for vesicovaginal fistulas was popularized by James Marion Sims (1813–1884). Sims observed that fistula repair using chromic and silk failed quickly due to inflammation. In 1858, Sims first described his use of silver wire in the *Anniversary Discourse* to the New York Academy of Medicine stating that 'fifty years hence the statistics of our hospitals will show a vast improvement in their bills of mortality after great operations, and this improvement will be due mainly to the use of silver as a suture'.[14] Sims was did not invent silver sutures,[15] but he introduced the material to a worldwide medical audience. His experiences generated the first successful treatment of a vesicovaginal fistula after Anarcha Westcott and other slaves underwent multiple failed attempts at fistula repairs.

Silver suture was employed for closing tissue under tension, for infected surgical fields, and for fistulas. Surgical supply companies advertised silver wire as being 'Certainly sterilized, and for this reason is frequently employed instead of silk or catgut …'[13] While metal sutures have the highest tensile strength of all suture material, they are difficult to tie.[16] Several special appliances were needed to twist and cut silver wire (Figure 1). A variety of needle drivers were developed to pass suture through tissue. Sims also developed retractors to place his sutures for vesicovaginal fistula repair. The use of silver sutures decreased when other synthetic pliable non-absorbable suture materials became available in the early 1900s. A

Figure 2
Note how the sutures are left long to avoid suppuration with the cervical stump externalized (from *Suppléments à la Médecine Opératoire* by Jean-Baptiste Marc Bourgery and Nicolas-Henri Jacob)

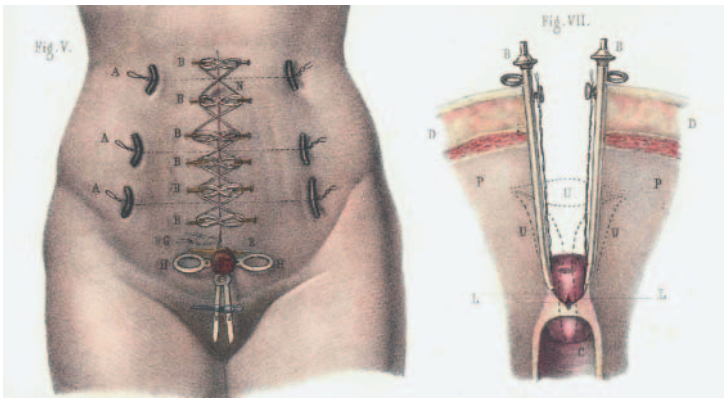

Figure 3
Carbolic acid generator. On 12 August 1865 Joseph Lister demonstrated his antiseptic technique on a compound fracture with the application of carbolic acid to the suture, the wound and its dressings

second reason for the decline of silver suture was innovation in carbolic acid sterilization of various suture materials mentioned below. In the present day, stainless steel may be used in gynaecology as retention sutures or through-and-through closure for complicated anterior abdominal wounds. Some metal sutures are now strands of stainless steel twisted together and coated to decrease the coefficient of friction and to improve handling. Inert metal materials with memory are now used mainly for staple closure and for surgical haemostatic clips.

Although the use of sutures was widespread in the 19th century, sutured wounds or incisions often became infected. Most surgeons of the era still preferred to cauterize wounds, rather than risk the patient's death from infected sutures. In 1867, a breakthrough for surgery was heralded by Lord Joseph Lister's publication entitled *The Antiseptic System: On a New Method of Treating Compound Fracture, Abscess, etc., with Observations on the Conditions of Suppuration*.[17] Lister was the first to make a connection between the presence of germs, which he termed 'the evil influences of the impure atmosphere', and infection. Before this time suture was left long with 'the ends left projecting from the wound'[14] (Figure 2). Lister speculated that if the bacteria in the interstices of suture material could be eliminated, the material could be safely left *in situ* with the ends cut short. In his first human experiment on 12 December 1867 with his new suture technique he noted, 'Healing took place without any suppuration, and with remarkable absence of swelling or tenderness'.[17] Lister used carbolic acid to clean suture material, instruments, dressing materials, and wounds (Figure 3). He also initiated a fundamental change in the preparation of suture materials when he steeped catgut in a solution of carbolic acid in five parts of olive oil with a very small quantity of water diffused through it (Figure 4). Unhappy about the handling qualities of catgut, he developed chromic catgut in 1881. Soon after Lister's time there continued to be issues with the technique of suture sterilization. In Dr Howard Atwood Kelly's 1906 edition of *Operative Gynecology*, he noted sterilization inconsistencies that sometimes required him to change operative procedures in order to avoid bacterial infection.[18]

Figure 4
Lister introduced the aseptic suture (silk soaked in carbolic) in 1869, followed by chromic catgut (prepared from sheep intestine and treated with 5% chromic acid) several years later

Contemporary sutures

Catgut was the staple absorbable suture material through the 1930s, although physicians used silk and cotton when a non-absorbable material was needed. The practice of packaging sutures in glass tubes filled with liquid was replaced by gamma irradiation sterilization in the late 1950s. Present-day catgut sutures are made using similar processes as those used 100 years ago. Catgut, now called plain gut, is made from United States beef as well as Indian or Pakistani sheep or goats. In order to extend the time the suture retains its strength in the body, the catgut sutures are treated with chromium salts to cross-link the collagen molecules. This treated suture was then called chromic gut to distinguish it from plain gut.

Standardization in suture size was instituted by the United States Pharmacopeia in 1937. The US Food and Drug Administration (FDA) began requiring approval of new suture material in the 1970s. Following the enactment of the Medical Device Amendment in 1976, the FDA required suture manufacturers to seek pre-market approval for new sutures. Manufacturers must comply with specific Good Manufacturing Practices, and guarantee that their products are safe and effective under these practices. Suture sterilization began with Lister's carbolic acid, though today sutures are sterilized primarily by ethylene oxide or gamma irradiation. Catgut diameter was refined to two-thousandths of an inch, assuring a more predictable tensile strength and handling characteristics. Similarly, the British Department of Health provides marketing authorization through the Medicines and Healthcare Products Regulatory Agency. After approval, the CE (Conformité Européenne) mark is placed on suture which conforms to 'essential requirements' for consumer safety in the European Economic Area.

In the 1960s, chemists developed over 40 new synthetic absorbable polymers including polyglycolic acid and polylactic acid.[19,20] Synthetic sutures are named based on the corporation, materials, or scientists who formulated them. For example, Ethibond® is the trade name for a polyester suture with a coating that is tightly bonded to the suture made by Ethicon, Inc (Somerville, NJ, USA). It was the successor to the Ethiflex® suture, which was a polyester suture that had a flexible polytetrafluoroethylene coating placed to improve its handling properties. Ethiflex was itself an extension of the uncoated Ethicon polyester suture called Mersilene®. The suture name Mersilene is a combination of Dr George Merson's name, and Terylene®, the common European trade name for polyester. Dr Merson invented the swaged suture and insisted that all swaged sutures include the prefix 'Mer-'. Thus the trade name Mersilene implies that the suture is polyester with a needle swaged onto it (M Weisberg, personal communication, 18 January 2010). Early braided polyester sutures were surpassed by nylon suture with better handling.

In the early 20th century, suture was marketed with a series of photographs dramatizing the art of surgery. The American photographer, Lejaren à Hiller, recreated dramatic scenes in the history of surgery using costumed actors and half-clad women as patients. Hiller portrayed Philip Syng Physick, Celsus, Ambroise Paré and others; he received the Edward Bok Award for advertising in

1937. Suture sales increased due to advertising and multiple contracts for the United States military in World War II. With increasing demand for more advanced suture Davis & Geck (Danbury, CT, USA) produced a synthetic absorbable suture called Dexon® in 1972. As with many suture development stories, the first Dexon® suture was altered in response to surgeon request, and a coated version was shortly released called Dexon Plus®. An improved coating that lowered the coefficient of friction during suturing was introduced as Dexon II® suture.[21] Building on these prior material developments suture is now becoming tailored for procedures and subspecialties. There are multiple new innovations for suture including a barbed suture for wound closure and anastamosis without the need for a conventional suture knot. Suture can be swaged on to various suture capture devices making pelvic organ prolapse surgery in the vascular recesses of the paravaginal space safer. The suture coating is also being medicated with antibiotics to prevent surgical site infections. Innovators continue developing a range of suture products for use in many specialized and medically important surgical applications.

Conclusion

An understanding of the origins of suture improves the appreciation for the use of contemporary sutures. Many modern surgical principles and practices – ligation, coagulation, wound closure and suture selection – have clear origins in history. Key contributions include Celsus inventing the use of suture ligatures for haemostasis, repopularization of suture over cautery by Paré, and sterilization of suture by Lister. The last 80 years have noted improvements on natural materials with the development of synthetic sutures that are custom-made for a particular anatomic structure and function.

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